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THE LIMITING HAND SKIN TEMPERATURE FOR UNAFFECTED MANUAL PERFORMANCE IN THE COLD

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The data of several studies suggest that manual performance is first affected by cold exposure somewhere between 55°F and 65°F hand skin temperature (e.g., Clark, 1959; Clark & Cohen, 1960; Gaydos, 1958; Gaydos & Dusek, 1958). However, this is only a suggestion since these investigations were designed to suit other experimental interests.

The purpose of the present study was to establish the lower limit of hand skin temperature (HST) for unaffected manual performance, and to determine the stability of this limiting temperature when duration of exposure is varied. On the basis of data reported by Gaydos (1958), and Gaydos and Dusek (1958), 60°F HST was studied as the possible limiting skin temperature for unaffected performance in the cold, and 55°F HST as the skin temperature initially associated with severe cold affect.

METHODS

Twelve white enlisted men, dressed in shorts and shoes, were exposed to a constant ambient temperature of 70°F and a relative humidity of 50%. Localized hand cooling was accomplished by the exposure of *S*'s hands to 10°F air within a refrigeration box. Hand skin temperature and knot-tying performance were measured as in the Clark and Cohen study (1960).

The experimental period lasted 4 days. Before cooling each day, *S* practiced tying five sets of 15 knots. *S*'s HST was then raised to 90°F with a heated muff and his hands inserted immediately into the cooling box. Experimental performance times were obtained on five different occasions during the cooling process: (*a*) upon entrance of *S*'s hands into the cooling unit; (*b*) when his HST had fallen to the appropriate criterion temperature, referred to as zero minutes' exposure at criterion; (*c*) after 20 minutes' exposure at the criterion HST; (*d*) after 40 minutes' exposure; and finally, (*e*) after 60 minutes' exposure.

On Days 1 and 2 of the 4-day experimental session, the criterion HST for half of the *S*s was 55°F, and for the other half 60°F. On Days 3 and 4 the criterion HSTs at which performance was measured were reversed to exclude practice bias from the data.

Although performance was always measured at the specific criterion temperatures, HST was permitted to vary ± 4°F from the criterion during the 1-hour exposure period. Thus, when *S*'s HST had fallen 4°F below criterion, his hands were withdrawn from the cooling unit and were exposed to the 70°F ambient temperature. When his HST had risen 4°F above criterion, his hands were reinserted into the cooling box. It should be noted that the ranges of 55° ± 4°F and 60° ± 4°F actually overlap.

RESULTS

All scores were adjusted for initial, preexperimental, performance level by subtracting *S*'s scores obtained at 90°F (HST) from each of his succeeding scores on a given test day. These deviation scores are shown in Figure 1 as joint functions of HST and exposure duration.

Analyses of variance of the adjusted data

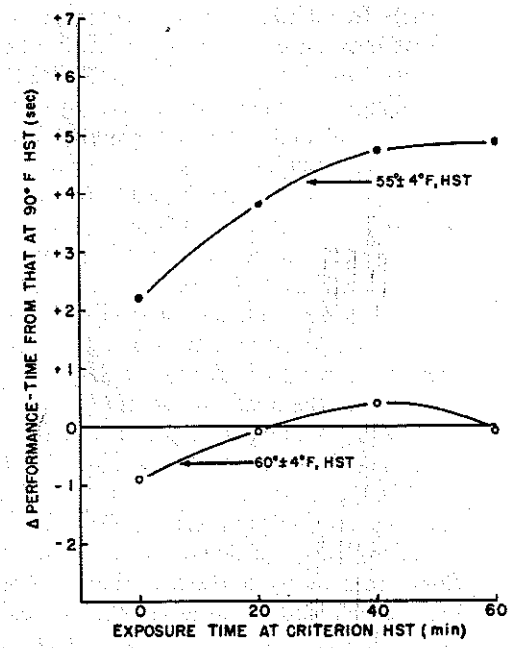

FIG. 1. Changes (Δ) in manual performance as functions of hand skin temperature and duration of cold exposure. (Positive changes are decrements.)

indicated significant ($p < .001$) main effects of HST and duration of exposure, but no significant interactions between the experimental variables (p's $> .10$). HSTs of 55°F were consistently associated with performance decrements and these decrements increased over exposure duration, becoming asymptotic after about 40 minutes of exposure. In contrast, performance at 60°F HST was never significantly different from that at 90°F HST, even though duration of exposure influenced performance somewhat at this skin temperature level.

To determine the stability of these findings for different groups of *S*s, the total subject sample was divided into two groups of six *S*s and the data of each group were analyzed for replication differences. None were found. Essentially the same effects of HST and duration of exposure occurred in both halves of the subject sample.

Discussion

The present data suggest quite unequivocally that the HST at 60°F is not associated with performance hindrance due to cold exposure when tasks similar to the present one are used (tasks requiring much joint movement). In addition, critical performance decrements may be expected when HST falls 5°F below this level, i.e., to 55°F HST. These findings remained unaltered by exposure duration and were completely supported by two samples of *S*s.

Presumably, some continuous function passing from no affect to severe exists between the HSTs studied here, but the determination of the function would be extremely difficult due to performance variability. Furthermore, a finer difference than 5°F between criterion HSTs would probably be unreasonable because of the need to use HST ranges to accomplish prolonged exposure periods.

Considering the findings of Clark and Cohen (1960), it should be noted that the present data for performance at 55°F HST could have been achieved only with a "medium" rate of hand cooling, that is, the cooling rate normally associated with exposing bare hands to air temperatures around 10°F. Very rapid hand cooling (exposure to, say, subzero air) could have permitted surface hand temperatures to drop to criterion levels before internal hand temperatures had been sufficiently lowered to hinder performance. Thus, the curve in Figure 1 for performance change at 55°F HST would have begun at the zero (no change) line, showing performance decrement only later in the exposure period. Very slow hand cooling (exposure to 20°F air or higher) could have negated the apparent influence of the present duration of exposure variable since internal hand temperatures might have become asymptotic before performance was first tested at the 55°F HST criterion. In the latter case, the 55°F HST curve in Figure 1 would have appeared as a straight line displaced above and parallel to the zero line, illustrating a constant performance decrement across the exposure period.

Summary

The hands of 12 enlisted men were cooled to 55°F and 60°F surface temperature on different experimental days. Performance times to complete a standard knot-tying task were obtained when *S*'s hands first reached the appropriate hand skin temperature, after 20 minutes' exposure at the criterion temperature, after 40 minutes' exposure, and after 60 minutes' exposure.

It was found that performance was severely hindered when hand skin temperature fell to 55°F, and that performance decrements at this skin temperature level were increasing exponential functions of duration of exposure, becoming asymptotic after about 40 minutes' exposure. In contrast, performance at 60°F hand skin temperature remained unaffected throughout the exposure period.

REFERENCES

Clark, R. E. The calculation of mean hand skin temperature in studies of manual performance in the cold. *PB Rep.*, 1959, No. 29. (Environmental Protection Research Division, Quartermaster Research and Engineering Command, Natick, Massachusetts)

Clark, R. E., & Cohen, A. Manual performance as a function of rate of change in hand skin temperature. *J. appl. Physiol.*, 1960, **15**, 496–498.

Gaydos, H. F. Effect on complex manual performance of cooling the body while maintaining the hands at normal temperatures. *J. appl. Physiol.*, 1958, **12**, 373–376.

Gaydos, H. F., & Dusek, E. R. Effects of localized hand cooling versus total body cooling on manual performance. *J. appl. Physiol.*, 1958, **12**, 377–380.

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